Use of Sr Isotopes to Determine Long-Term Average Vadose Zone Infiltration Flux at Hanford 200W Area

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RESEARCH OBJECTIVES

Infiltration rates are an important variable in assessing contaminant transport at the Hanford Site, where the majority of the contaminants are contained in the upper 30 m of a thick (~70 m) vadose zone. The transit time to the aquifer for a given contaminant largely determines the remediation action, especially for mobile radioactive contaminants. Efforts to quantify infiltration rates at the Hanford Site have been hindered by the complexity of the hydrogeologic setting, the thick vadose zone, and recent anthropogenic disturbances. Independent estimates of infiltration rates range from 0.01 mm/yr to 200 mm/yr, depending on the method and surface cover.

Using variations in the natural strontium (Sr) isotopic compositions of vadose zone pore waters and sediments, the infiltration flux can be quantified using a simple one-dimensional reactive transport model. The strontium isotope ratio ($^{87}Sr/^{86}Sr$) of pore water is a very sensitive indicator of interaction with the rock matrix. Because of the relatively low concentration of Sr in the pore water relative to the sediments, even minor exchange between the solid and fluid phases will quickly shift the pore-water Sr isotope ratio towards that of the rock. The pore water $^{87}Sr/^{86}Sr$ value is thus controlled by a balance between the infiltration flux and weathering of the sediments.

APPROACH

Strontium isotope ratios were measured in the pore water, acid extracts, mineral separates, and sediments of a 70 m vadose zone core in the 200W Area of the Hanford/DOE complex in eastern Washington State. Using an estimate of the bulk weathering rate for the sediments, the steady-state reactive transport model for Sr in the vadose zone was inverted to solve for the infiltration rate (see Maher et al., 2003). This method is currently being applied to other locations around the Hanford Site.

ACCOMPLISHMENTS

Given a range of weathering rates based on sediment mineralogy, the infiltration flux for the 200W Area is constrained at between 7 ± 3 mm/yr (Figure 1). Non-steady-state models spanning the last 15 kyr reveal that the profile is very close to steady state; therefore, these infiltration flux values are applicable over at least this time span. The transit time for meteoric water to percolate from surface to the water table is in the range of ~1,200 years.

SIGNIFICANCE OF FINDINGS

The method of inferring infiltration rates using Sr isotopes provides a novel method for quantifying fluid flow in the vadose zone. This method is advantageous in that it does not require disturbance of the site prior to measurement (e.g., lysimeters), it does not rely *ab initio* on assumptions regarding atmospheric and geochemical parameters (e.g., Cl mass balance), it can be applied to deep heterogeneous vadose zones, and it provides a long-term (~1–10 kyr) average of the infiltration flux.
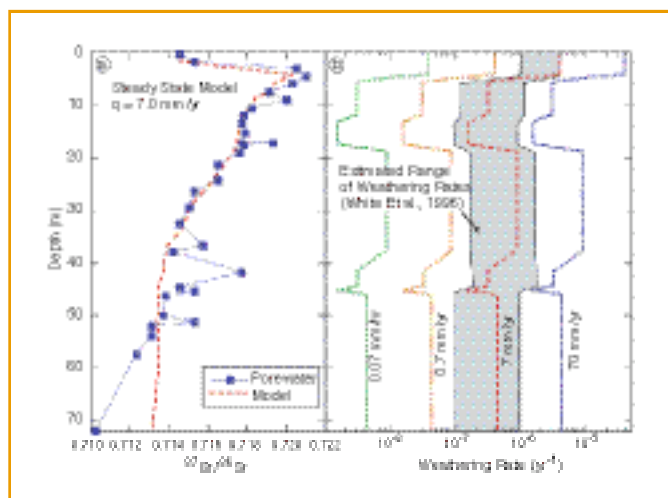

Figure 1. Steady-state model best-fit trajectory and weathering rate profile: (a) the $^{87}Sr/^{86}Sr$ values for the pore waters decrease systematically with depth, from a high value of 0.721 near the surface towards the bulk sediment average value of 0.711; (b) weathering rates required to fit the data for various infiltration rates, and the range of estimated rates based on soils data from White et al. (1996). The models suggest that the infiltration flux for the site is 5 to 10 mm/yr. The method shows potential for providing long-term *in situ* estimates of infiltration rates for deep heterogeneous vadose zones.

RELATED PUBLICATIONS

Maher, K., D.J. DePaolo, and M.E. Conrad, Vadose zone infiltration rate at Hanford, Washington, inferred from Sr isotope measurements. Water Resources Research 39 (8), 1204, 2003.

DePaolo, D.J., M.E. Conrad, and K. Maher, Oxygen and hydrogen isotopes in pore fluids from a 70 m thick vadose zone. Vadose Zone Journal, 2003 (submitted).

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